USE OF ATRAZINE IN CONIFER PLANTATIONS -

FINAL REPORT

ON A

ONE YEAR FIELD STUDY

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Abstract: Atrazine (2-chloro-4, ethyl amino-6, isopropyl-amino-1,3,5 s-triazine) was studied over a one year period to determine its effectiveness in conifer plantation applications. On two sites having different soil textures, five conifer species were sprayed at one of four times during the growing season, using rates of 2, 4, or 6 lb of active herbicide per acre. Fraser fir (Abies fraseri) sprayed at June 2 showed defoliation and possible death of the terminal shoots at all rates; possible reductions in vigor were also observed on blue spruce (Picea pungens) sprayed at June 2 with 6 lb/A, and on Douglas fir (Pseudotsuga menziesii) sprayed at April 25 with 6 lb/A. Other species-time combinations showed no apparent damage from atrazine applications. April 25 and June 2 applications were judged to be equal in effectiveness in controlling weed competition; later applications were much less effective during the initial growing season. For the April and June treatments, increased control was achieved by increasing application rates from 0 to 2 and 2 to 4 lb/A; 4 and 6 lb/A applications did not differ in effectiveness. Based on these results, it appears that atrazine can be used relatively safely and effectively in young conifer plantations, if care is exercised to avoid direct contact with growing shoots.

INTRODUCTION

To assure good initial survival and subsequent growth of newly established conifer plantations, competition from herbaceous vegetation present on the planting site must be controlled. For Scotch pine (Pinus sylvestris), the most common Christmas tree species grown in Ohio, undesirable weed competition can reduce survival and growth after three years by over 30% (2). For species with more demanding site requirements such as Fraser fir, losses can be even more pronounced. Weed competition can also cause loss of lower branch whorls, resulting in poorly formed Christmas trees. To a commercial grower, such losses can often mean the difference between a profitable operation and an unsuccessful one.

Fortunately, many methods of controlling weeds in conifer plantings are available. Before the advent of herbicides, mechanical means such as scalping, furrowing, and mowing were employed to control weeds on plantation sites. However, these methods have many disadvantages which have been well documented by others (1,9). The same authorities have demonstrated that proper use of herbicides is equal to hand scalping in effectiveness in controlling weeds. From the economic standpoint, herbicides are clearly the best method of weed control available to Christmas tree growers when factors such as time and labor involved in weed control treatments are considered.

Herbicides used for weed control in Christmas tree culture can be conceptually divided into two broad classes, based on their modes of action. This might be somewhat of an oversimplification, but should suffice for discussion purposes. The first type of herbicide would include those which act through the roots and are used primarily for pre-emergent weed control. Simazine is probably the most widely used herbicide of this type, so it will be used as a representative example in the following discussion. Because it lacks contact action, simazine can be applied directly over conifers without damage, but to be effective in controlling weeds, it must be applied early in the season before vegetation begins growth. Simazine is not effective in controlling broadleaved plants, but shows very good control of many grasses. Its main strength is its persistence and slow breakdown in the soil, which can maintain control over one or more growing seasons.

The second type of herbicides are those which act primariltу through direct contact action with the foliage, although many also work through the roots. Because these herbicides are very soluble and easily translocated through plant tissue, they are most effective when applied during the period of active growth. Some work best in controlling grasses (eg: dalapon), some work best on broadleaved plants and woody vegetation (eg: 2,4-D) while others are non-selective and work over a wide range of weeds (eg: amino-triazole, paraquat). Unfortunately, these herbicides will very often injure conifer seedlings severely and must be applied as a directed spray, which greatly reduces their utility. These herbicides are broken down quickly in the soil, and as a result, do not have a significant residual effect.

An ideal herbicide for Christmas tree culture would be one which combines the best characteristics of both the above types. To enable a grower to maintain flexibility in scheduling spraying operations, and to avoid other difficulties such as off-center planting in rows previously treated with herbicide, a herbicide should be effective when applied at any time over a reasonably long period. To avoid directed spray treatments, the herbicide should not damage trees when applied directly over them. Atrazine, a triazine herbicide used extensively in corn production, combines the capability to kill vegetation after it begins growth with a residual effect in the soil similar to that of simazine. However, questions remain regarding the direct effects of atrazine applications over conifers at various stages of growth.

Because atrazine shows selective action with many plants, it is entirely possible that the same type of selectivity would be exhibited with some or all species of coniferous trees. Experts seem to disagree on this subject. White (10) recommends that atrazine not be applied over growing shoots of conifers. Ahrens, et al (1) report discoloration and defoliation in white pine (Pinus strobus), white spruce (Picea glauca), and balsam fir (Abies balsamea) at rates of 4 and 6 lb/A. However, Newton and Overton (6) in their discussion of the synergistic effects of atrazine, dalapon, and 2,4-D mixtures in dormant season applications over conifers assume that the direct effect of atrazine alone on Douglas fir and grand fir (Abies grandis) is negligible. Overall, specific data are scanty regarding the direct and indirect effects of atrazine on various conifer species when applied at various rates and times, especially under conditions encountered by growers in Ohio.

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METHODS

In the spring of 1973, a field study was establised at the Ohio Agricultural Research and Development Center's Pomerene Forest Research Center near Coshocton, Ohio. The objectives of the study were to answer the following questions:

- Can atrazine be applied over conifers at any time during the year without damage to them?
- Are some conifer species more sensitive to atrazine applications than others?
- Is atrazine effective in controlling weed competition when applied after weeds begin active growth?
- If atrazine proves to be valuable, what are the optimum rates of herbicide application, considering variables such as species of conifer, timing of treatments, and soil texture?

A split-split-plot experimental design was used to test the main effects and interactions of four variables: species of conifer, time of application, rate of application, and soil texture. The main plots consisted of rows of one of five representative conifer species: Scotch pine, white pine, Douglas fir, blue spruce, or Fraser fir. Each row (main plot) was subdivided into four sub-plots, which were sprayed at one of four times during the growing season: April 25, June 2, July 7, or August 11 (five week intervals). Each time of application (sub-plot) was further divided into three five-tree sub-sub-plots, which were sprayed with either 2, 4, or 6 lb of active herbicide (atrazine 80W) per acre. Each row also contained a five-tree check plot which received no treatment.

Rows were spaced 8 feet apart. Within sub-sub-plots, trees were spaced at two-foot intervals, with four feet between each five-tree plot in the row. Each block of five rows was replicated five times on a bottomland sandy loam soil, and four times on an upland silt loam soil. Vegetation on both sites consisted mainly of perennial grasses. Both areas had been pastures.

Using a hand-calibrated backpack sprayer, treatments were applied in a two-foot band directly over the trees, which were exposed, if necessary, by laying back any over-topping weeds. Times of application were spaced at five week intervals in an attempt to test susceptibility of all species at various stages of growth. Rates used were chosen to represent the currently recommended range of dosages for coarse (2 lb), medium (4 lb), and fine (6 lb) textured soils. Plots were mowed between rows at intervals throughout the summer.

On the date of the time 1 treatments (April 25), vegetation had been growing actively for two to three weeks and was 12 to 18 inches tall. Trees had been planted a week previously, and were still in a nearly dormant condition, with the possible exception of some pines which had just begun to candle. Five weeks later (June 2) when the time 2 treatments were applied, vegetation was still growing actively and was 2 to 3 feet tall on both sites. Fraser fir had recently begun growth and was in a very succulent stage; blue spruce was farther along and had nearly completed height growth; the pines and Douglas fir had completed growth and were forming buds. All plots treated at time 1 showed excellent control of vegetation, with the different rates of application clearly distinguishable by the degree of vegetation mortality present.

By time 3 (July 7) vegetation on the untreated plots had nearly ceased active growth and was essentially the same height as the previous time of application. All trees had completely ceased active height growth, and had begun to harden off. Time 2 treatments showed very good control of vegetation, with nearly complete mortality of the tops of weeds at the 4 and 6 lb rates. As in time 1, each rate of application could be easily distinguished based on the amount of control achieved. Time 1 plots continued to show good control, with some minor reinvasion beginning to take place. Some Fraser fir sprayed at time 2 showed a bleached-out appearance and needle curling on the current year's growth; other species-time combinations appeared to be normal.

Five weeks later at time 4 (August 11), all trees had nearly completed hardening off. Weed vegetation had the same appearance as in time 3, but was in a more advanced stage of growth. Many time 1 and 2 plots showed heavy reinvasion of fall panicum (*Panicum dichotomiflorum*), a species not present in the original vegetation association. Growth of this species, which was over 2 feet tall in many cases, was densest on bottomland site plots treated at time 1 with the 4 and 6 lb/A rates. Time 2 plots which had not achieved total kill of vegetation (mostly 2 lb applications) showed some regrowth of the indigenous vegetation. Time 3 applications showed much less control than the previous two times had shown after the same time period; at best, perhaps 75% of the vegetation tops were killed at the 6 lb rate. The apparent damage noticed in July on the time 2 Fraser fir plots now appeared as a slight to severe localized defoliation of the current year's growth. However, the stem and newly formed terminal buds appeared to be alive and otherwise normal.[1] No other species-time combinations showed any such effects.

Throughout the summer, problems were experienced from woodchucks which had invaded both sites and destroyed or damaged many plots. Some losses also resulted from mowing accidents.

The following winter (January 20) survival was counted for all plots. Average height growth of each plot during the previous growing season was measured, along with the original and total height of the check plots. Attempts were also made to evaluate weed control existing at this

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[1] Although buds appeared to be normal on Jan. 20, observations made the following spring (May 5) seem to show that these buds were not going to open normally. If this proves to be the case, the damage reported on Fraser fir is more serious than a slight defoliation - mortality of the entire previous year's growth would be a more accurate description of the damage.

time, and the vigor of trees in each plot. Weed control was rated on a 1 to 4 point scale (in ½ point increments), 4 equalling total eradication, 1 equalling no difference from the check plots. Since all vegetation tops were dead and fallen over at this time, ratings were based entirely on weed density, which could be easily evaluated at this time. Because it was known that the time 1 and 2 plots had been reinvaded by a species not originally there (fall panicum), these plots were rated as though this species were absent. A separate tally was kept of reinvasion, again based on density of plants in the reinvaded plots.

Vigor ratings were based on a three-point system as follows:

3 = healthy green appearance; no obvious needle loss or presence of dead foliage.

2 = presence of a substantial amount of dead foliage or defoliation; also used to indicate an overall chlorotic appearance of some spruce plots. Very good probability of survival until next season.

1 = vigor markedly reduced due to severe defoliation or dominant presence of dead foliage; probability of survival questionable to doubtful.

Plots not falling into one of the above categories were rated as 2.5 or 1.5.

Data were analyzed using analyses of variance for a split-split-plot design. Standard errors for comparisons among treatment means were calculated using formulas given in (5). For the upland site variables used in the analyses were (1) height growth, (2) ratio of height growth of treated plots to height of check plots (% height growth), (3) vigor, and (4) control of weed competition. Due to a time limitation, only the vigor variable was used in the analysis of the bottomland site. Because trends appear to be similar for both sites, remarks pertaining to the analysis of the upland site should also hold for the bottomland site. Where this is not the case, appropriate comments will be made.

Due to significant losses of portions of some plots from woodchuck and mower damage, survival data were not analyzed, as the results would only be misleading.

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DISCUSSION

Superficial analysis of the experimental procedure employed in this study would seem to indicate that its one year time span would not reveal the true value of atrazine (if any) in conifer plantation weed control. In some respects this is true. For example, an entire rotation of Christmas trees would not be an unreasonably long period for a study designed to determine the optimum rate and timing of atrazine treatments. However, this was not one of the main objectives of the study, because it was not established that atrazine could be used safely and effectively in applications directly over trees.

From the standpoint of answering the question of conifer sensitivity to direct atrazine applications, the one year span of this study was actually an advantage. It is generally established that the growth and overall vigor of newly planted seedlings is determined mainly during the previous year (1). As a result, competition effects (unless they are extremely severe) such as growth suppression and vigor reduction generally take longer than one growing season to become apparent. Data from this study indicate that this relationship holds, as the check plots receiving no herbicide treatment showed no significant reductions in vigor compared to treated plots; in fact, check plots were slightly higher in vigor ratings. Consequently, it was not necessary to separate the indirect, detrimental effects of weed competition from any possible direct detrimental effects resulting from atrazine applications as others advocate (6), because only the direct herbicide-induced effects would be apparent within one year.

According to the above assumptions, any significant detrimental changes in vigor or height growth of the trees during the first year could be attributed directly to the effects of atrazine. Environmental factors (frost damage, moisture gradients, etc.) should be eliminated from the net herbicide effect by the randomization of treatments and analysis of variance. However, vigor and growth are not the only important considerations in establishing conifer plantations. Survival through the first year is also an important factor, possibly the most important one in this respect. Valid survival counts would definitely have added to this study by helping to separate out any differences between rates of application. However, survival data are not necessary to determine the direct effects of atrazine on conifers, because the worst "damage" (decrease in vigor) observed amounted to a defoliation of the terminal shoots. In other words, no applications came close to killing any tree, so the direct (negative) effect of atrazine treatments used in this study on survival can be assumed to be non-existent.

A problem with this hypothesis is that less direct effects of atrazine through root uptake do not manifest themselves as localized defoliation, but rather as a slow decline in vigor ultimately resulting in death after one or more years (1). It is possible that some trees might have been killed by the early-season, high-rate treatments on the coarse textured site, in which case it would seem that the vigor variable would not record the true effect of the herbicide action. Another complicating factor enters here, because one would expect the late April applications to produce the best survival (trees would be free from competition stresses for the longest period) in the absence of detrimental herbicide effects. Here, survival data would have been valuable to obtain a clearer picture.

However, vigor means for time 1 treatments, as well as time-species interaction means, do not show a reduction in vigor from the early-season treatments; in fact, on the bottomland site time 1 applications show slightly greater vigor (although not signifcant). If any detrimental effects resulting from atrazine uptake exist, they would certainly have been apparent by the following winter when the vigor evaluations were made. Since no time 1 plots experienced complete mortality, the vigor variable as defined in the study can be used as an indicator of the indirect, as well as the direct, effects from atrazine treatments.

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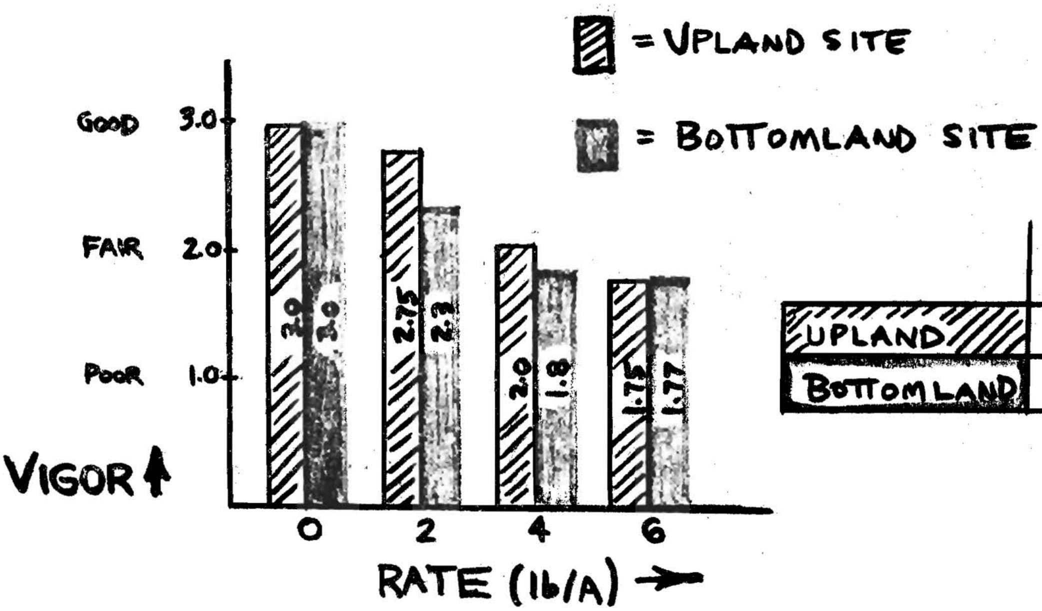
In the analysis of the vigor variable for the upland site, the time and rate main effects, the species-rate, time-rate, and species-time-rate interactions were all highly significant. The species main effect was not significant, and the time-rate interaction approached significance at the 5% level. According to the assumptions outlined above, the observed differences should reflect only detrimental changes in vigor, which is indeed the case. The significant results are due primarily to the observed defoliation of the time 2 applications over Fraser fir, which was recorded as 2.0 $\pm$.5 vigor, depending on the amount of defoliation present. Figure 1 summarizes the effects of the time 2 Fraser fir applications for both sites, broken down by rates.

On both sites there was no difference between the 4 and 6 lb rates in the amount of defoliation caused. The difference between the 2 lb rate and the 4 and 6 lb rates was highly significant on both sites. On the upland site the 2 lb applications did not differ significantly from the check plots, whereas on the bottomland site, the difference between the controls and 2 lb treatments was highly significant. The defoliation was undoubtably caused by direct absorption into the succulent foliage, and should not be related to site factors such as soil texture. Therefore, it can be concluded that the differences between



	STD. ERROR	LSD .01
UPLAND	.180	.50
BOTTOMLAND	.155	.40

Figure 1. Fraser fir vigor - June 2 applications (average of 9 replications)

sites of the 2 lb applications was due mainly to slight calibration errors. Nevertheless, a general trend is clearly evident from the data. Increasing rates of application did cause greater defoliation, although the 4 to 6 lb increase did not cause a similar increase in visible damage.

The only other significant decrease in vigor observed was on blue spruce, time 2 at the 6 lb rate only. This was not a defoliation, but rather an overall chlorotic appearance, which was rated as an average vigor of 1.75 over 4 upland site replications of this species-time-rate combination. Since this effect was noticed on the upland site only, it is possible that the reduction in vigor was caused by a random agent other than the atrazine treatments. A safer interpretation would be that the spruce was in a more susceptible condition on the upland site than on the bottomland site on the date of the time 2 applications, and was more affected by the high rate of herbicide. This interpretation suggests that spruce is more resistant to direct atrazine applications than Fraser fir (spruce vigor at rates 2 and 4 were perfect 3.0's), either because it was more advanced than Fraser fir in terms of growth or because of inherent differences between spruce and fir in sensitivity to atrazine. In view of these results, it is possible that blue spruce is somewhat susceptible to high rates of atrazine applied during the latter stages of active growth, but is more resistant than Fraser fir to lower rates (1 to 4 lb/A) applied at the same time.

Douglas fir showed significant reductions in vigor at all times of application, but this was probably due to the extreme variability in quality of the Douglas fir planting stock used, especially since reductions were sometimes most pronounced at the 4 lb rates. If any reduction in vigor due to herbicide treatments had taken place, certainly the 6 lb rates would show the most detrimental effects. However, both sites do show significant reductions at time 1, rate 6 (upland = 2.5; bottomland = 2.4), which could possibly indicate minor damage from atrazine applications, either from contact effects or uptake over the growing season. Again, a safe interpretation would be that Douglas fir is somewhat susceptible to high rate, early season atrazine applications. Unfortunately, this cannot be stated with certainty, because vigor reduction definitely took place due to other causes.

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Analysis of the height growth and % height growth variables show identical results, so to simplify matters, height growth only will be used in the following discussion. Significant time effects and time-species interactions indicate that reduced growth occurred at a certain time of application, which was more pronounced with certain species.

Table 1 shows that the average growth of time 1 applications was .6 cm less than times 2, 3, or 4. This difference is statistically significant, but of little practical importance other than to show a possible trend. The time-species breakdown in Table 1 further indicates that the species interaction with time 1 applications is due almost entirely to white pine, which grew significantly less (2.1 cm) than the average of times 2, 3, and 4. Scotch pine and

SPECIES	TIME OF APPLICATION: APRIL 25	JUNE 2	JULY 7	AUG 11	SPECIES MEANS:
SCOTCH PINE	14.5	15.4	14.6	15.9	15.1
WHITE PINE	8.75	10.2	11.8	10.7	10.3
DOUGLAS FIR	4.1	4.6	3.8	2.9	3.8
BLUE SPRUCE	4.2	3.8	4.2	4.3	4.1
FRASER FIR	4.4	5.2	5.2	5.3	5.0
TIME MEANS:	7.2	7.8	7.9	7.8	

COMPARISON:	STD. ERROR	$LSD_{.01}$
BETWEEN TIME TOTALS	.216	.58
BETWEEN TIMES WITHIN SAME SPECIES	.484	1.30

Table 1. Height growth (cm) of individual species for each time of application (averaged over all rates of application and 4 upland site replications).

Fraser fir also showed reduced growth at time 1, but the difference (.8 cm) was barely significant at the 5% level and is of little importance. Douglas fir and blue spruce actually showed increased growth at time 1 (.4 and .1 cm, respectively), but these differences are not significant.

The analysis of variance was not calculated for the bottomland site, so it is difficult to say whether this reduction in growth at time 1 is a genuine phenomenon. Simple comparisons between time of application means for white pine growth on the bottomland site do not show this trend. (Time 1 growth was actually slightly greater than the average of times 2, 3, and 4 - 9.0 vs 8.7 cm) Also, data were analyzed under the assumption that the variance within treatments is equal, which was definitely not the case with height growth or % height growth variables, because pine growth varied over a much wider range than did growth of spruce or the firs. Calculation of a more appropriate (larger) standard error for the pines would probably eliminate any significant differences in the results. Unless this growth reduction is observed in further trials, it is probably safe to assume that no adverse effect on height growth results from direct atrazine applications, especially since the time 2 Fraser fir (which showed the most obvious damage) did not show any reduction in growth.

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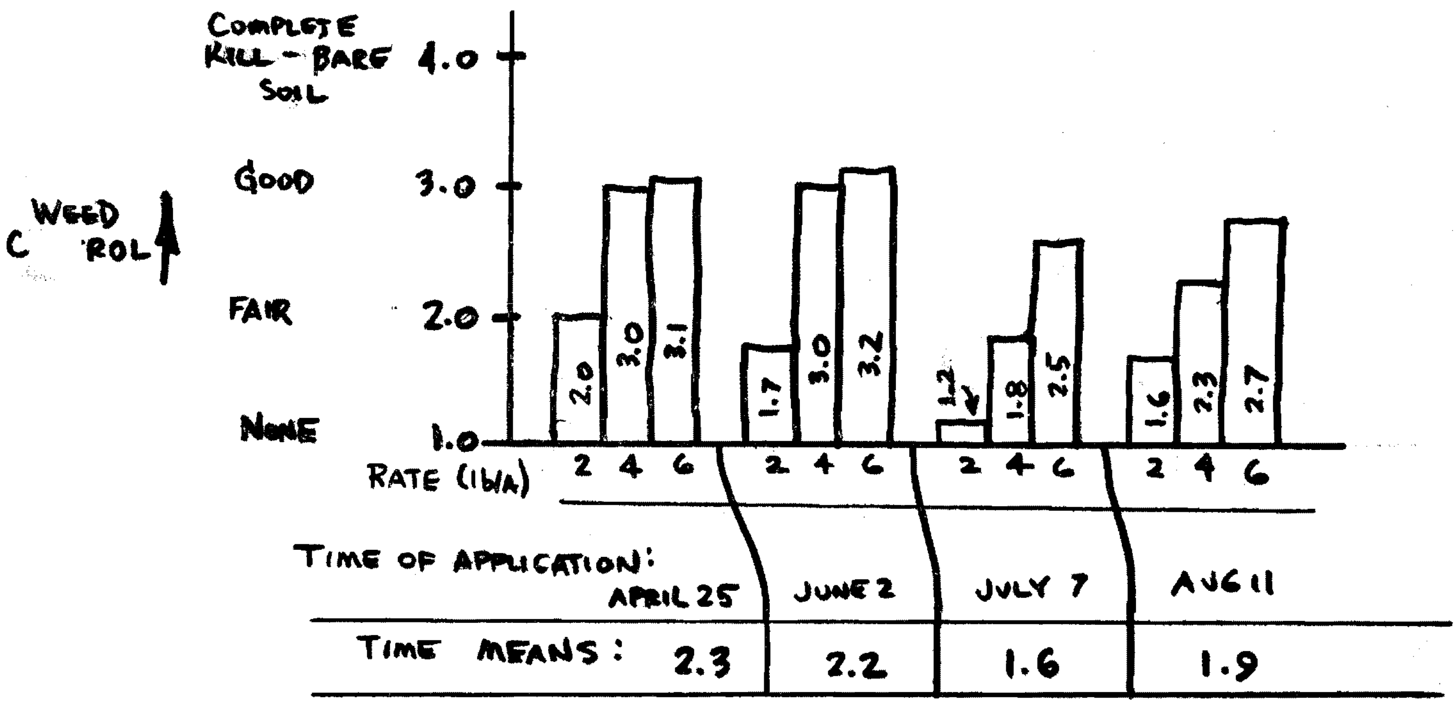
The analysis of the control of competition variable shows strongly significant time and rate main effects and time-rate interactions. Figure 2 shows weed control achieved by all time-rate combinations.

Averaged over all rates, times 1 and 2 did not differ; time 4 was significantly less effective than times 1 and 2; and time 3 was significantly less effective than time 4.



COMPARISON:	STD. ERROR.	$LSD_{.01}$
BETWEEN TIME TOTALS	.0747	.20
BETWEEN RATES WITHIN TIMES	.126	.34
BETWEEN TIMES AT SAME OR DIFFERENT RATES	.132	.35

Figure 2. Weed control existing after one season from all rate-time combinations (average over four upland site replications)

Rate totals must be considered by individual times of application. At times 1 and 2, a significant increase in control was achieved by the 0 to 2 and 2 to 4 lb/A increases in rate; increasing from 4 to 6 lb/A did not increase control significantly. At time 3, an increase from 0 to 4 lb/A was required to achieve some control. Increasing from 4 to 6 lb/A also produced a significant increment, but totals for time 3 were much less than time 1 or 2 totals at corresponding rates. Control trends resulting from time 4 treatments are similar to those of time 3, with slightly better control at each rate.

Data definitely reinforce observations made throughout the study. Best control after one season was clearly achieved at times 1 and 2, rates 4 and 6 lb/A; effectiveness during the initial year of later season applications drops off markedly, perhaps even more so than the data indicate. Somewhat puzzling was the greater control at time 4 over that of time 3: one might expect the opposite to be the case. Weed vegetation was probably in a similar state of susceptibility at times 3 and 4, resulting in similar initial effects resulting from both treatments. However, time 3 treatments had an additional 5 weeks to recover, and consequently would show less control at the end of the growing season than the time 4 treatments, which had probably lost the potential for regrowth by the time the treatments were applied.

In one sense the data are misleading, because the 2 lb applications at times 1 and 2 compare infavorably to later, high rate applications in terms of control existing at the end of the growing season. In terms of relieving competition stresses during the critcal summer period, the 2 lb early season treatments were probably more effective, even though the residual effect did not last until winter. In other words, the focus of attention should be upon the benefits derived by the trees (which are difficult to measure in one year as outlined earlier), not the amount of vegetation killed, although there is certainly a direct relationship between the two factors.

Data for the bottomland site were not analyzed. Since both sites had similar vegetation, one would expect similar trends to exist, differing only in rate of application due to differences in soil texture. This is only partially true. Initial control achieved on the bottomland site was very similar to that achieved on the upland site, but the residual effects were much less on the bottomland site. This is undoubtably due to the greater moisture content of the bottomland soil (due to a higher water table), which, when combined with the coarse soil texture, caused rapid leaching of the very soluble atrazine molecule. Observations made the following spring show virtually no control remaining at any rate-time combination on the bottomland site, excepting some time 4, rate 6 treatments. However, on the upland site most time 1 and 2, rate 4 and 6 treatments still showed very good control, which was equal to time 4,6 lb treatments (which also showed very good control) in many cases.

Another factor which differed betwee sites was the observed reinvasion of fall panicum on the time 1 and 2 treatments. This was more severe on the bottomland site, and was most pronounced on plots treated with 4 and 6 lb/A. Although this result was unexpected, further investigation reveals that this problem is very common where atrazine is used exclusively in corn production (8). Apparently, good early season weed control resulting from atrazine treatments creates an ecological niche particularly suited for the establishment and growth of fall panicum, which is resistant to atrazine. If fall panicum is a problem, continued exclusive use of atrazine would undoubtably be detrimental. Perhaps the addition of another herbicide such as simazine would prevent germination of panicum seeds and thereby maintain control over longer periods.

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CONCLUSIONS

Based on the results of this study, it appears that atrazine can be used with considerable safety in direct applications over conifers, if care is exercised to time applications when trees are not growing actively.(May 1 to mid-June, depending on species and location). Unfortunately, no applications were made during the period of active growth for most species (mid-May); only Fraser fir was in a highly susceptible condition when sprayed. It is very possible that damage would result to the pines, Douglas fir, and blue spruce if they were sprayed at this time, but this cannot be determined from this study.

It is doubtful that atrazine applied at recommended rates would ever kill any conifer seedling, so in this respect, atrazine is much safer to use than other contact action herbicides. This study shows that the direct contact damage from atrazine occurs only on newly formed foliage and possibly stem tissue. Foliage over 5 weeks old is apparently totally resistant to atrazine's contact effects, probably due to the formation of a protective cutin layer which prevents absorption into leaf tissue. It is possible that resistance to atrazine is due to physiological, as well as morphological, factors, but this would require a detailed physiological study to determine.

In terms of controlling weeds, atrazine is apparently effective over a reasonably long time span compared to simazine, which is effective only when applied pre-emergence. When applied over vegetation which is not inherently resistant to atrazine, excellent control can be achieved through early June, after which effectiveness drops off rapidly. This would allow a grower to time his herbicide treatments based entirely on the condition of the trees (to avoid possible damage) with the assurance that good weed control will result. Later season applications would seem to be unwise, because of their reduced effectiveness and tardiness in relieving moisture stress. Late season applications might have a significant effect during the following season, but there is no reason to apply treatments in the fall, since their residual effects would be greatly reduced over the winter months due to leaching and breakdown.

On sites similar to those used in this study, there seems to be no reason to apply more than 4 lb of active herbicide per acre. Greater rates result essentially in overkill of vegetation and have the potential to damage trees through root uptake. Also, there seems to be no difference in persistence between the 4 and 6 lb rates, which agrees with the observations of others (4,7) that atrazine breakdown is related more to site factors such as moisture, temperature, and texture, than to the initial rate of application. This is an important factor if atrazine-simazine mixtures are considered. For example, adding 2 lb of simazine to 4 lb of atrazine to control species resistant to atrazine and maintain a longer-lasting effect would seem to be preferrable to using 6 lb of atrazine alone.

Further work is needed to relate sensitivity of conifer species to atrazine directly to stages of growth, rather than to arbitrary times during the year. If this is done, any species which might be resistant to atrazine can be detected. However, atrazine use in conifer plantations need not wait for more conclusive data. Atrazine definitely has much to recommend it, because it combines the ability to kill vegetation after it begins growth with the ability to use non-directed spray applications if the trees are not growing actively. Its drawbacks would include resistance of some weed species (notably fall panicum), rapid loss of residual effects on wet, coarse textured soils, and most importantly, its potential to produce severe damage and defoliation in some species if applied at the improper time.

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